

COMPRESSED NATURAL GAS VEHICLES

Two different CNG vehicle models were tested during this study. These models include the Dodge B250 van and the Dodge Caravan minivan. Both vans are dedicated natural gas vehicles, which means they are designed to operate on CNG only. To make fuel-to-fuel emissions comparisons, it was necessary to test closely matched gasoline vehicles. The AFV and the gasoline models are

both classified by the EPA as "heavy light-duty vehicles." See Table 2 on page 2 for the EPA intermediate useful life standards for the vans.

As with the other fuels, an overview of the general trends is presented first and then the detailed results for each of the test vehicles are presented in subsequent sections. Table 30 and Table 31 show summary

comparisons of the average CNG emissions compared to the average RFG emissions. As in the sections on methanol and ethanol, the shaded blocks indicate differences between the averages that were statistically significant (at the 95% confidence level). Plus signs indicate that the average CNG emissions were higher than the average RFG emissions, and the minus signs indicate that the

Table 30. Summary Comparison of Average Emissions Results from CNG versus RFG

	Dodge B250								Dodge Caravan
	Lab 1		Lab 2			Lab 3			Lab 1
	Round 1	Round 2	Round 1	Round 2	Round 3	Round 1	Round 2	Round 3	Round 1
Regulated Emissions									
NMHC	-	-	-	-	-	-	-	-	-
THC	-	-	+	+	+	+	+	+	-
CO	-	-	-	-	-	-	-	-	-
NO _x	-	-	-	-	+	-	-	-	-
Evaporative Emissions									
THC	-	-	-	-	-	-	-	-	-
Greenhouse Gases									
CO ₂	-	-	-	-	-	-	-	-	-
CH ₄	+	+	+	+	+	+	+	+	+
Aldehydes									
HCHO	-	-	+	-	+	-	-	-	+
CH ₃ CHO	-	-	-	-	-	-	-	-	-
Fuel Economy									
mpg	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
mpeg	-	-	-	-	-	-	-	-	-

"+" Indicates results from CNG tests were higher than RFG tests

"-" Indicates results from CNG tests were lower than RFG tests

Highlighted blocks indicate a significant statistical difference.

Table 31. Summary Comparison of Average Speciated Hydrocarbon Results from CNG versus RFG

	Dodge B250 Van	
Air Toxics	Lab 1	Lab 3
HCHO	-	-
CH ₃ CHO	-	-
1,3-butadiene	-	-
Benzene	-	-
Total PWT	-	-
Ozone Reactivity		
OFP	-	-
SR	-	-

average CNG emissions were lower than the average RFG emissions. Table 30 includes mass emissions results from the B250s that were tested over multiple rounds at all 3 labs, and more limited results from the Caravans that were only tested during a single round at Lab 1. Table 31 includes results from detailed hydrocarbon speciations of emissions from the B250 tests performed at Labs 1 and 3.

Table 30 shows that there tend to be statistically significant differences between the average emissions from the CNG and RFG B250 vans, and that these results tend to be fairly consistent from lab to lab and from round to round. The average NMHC, CO, CO₂, CH₃CHO, and fuel economy results were significantly lower from the CNG tests than the RFG tests for all three labs and in all three test rounds. Average CH₄ emissions were consistently higher from CNG than from RFG. NO_x and "evaporative" hydrocarbons tended to be lower from the CNG tests, but in some cases the differences were not significant, and in one case (Lab 2, Round 3) the average NO_x emissions were higher from CNG. The evapora-

tive emissions test is a measure of the hydrocarbons emanating from two, 1-hour soaks in a sealed room with the engine off. Dedicated gaseous fuel vehicles typically do not have evaporative control systems because the fuel system is said to be sealed under pressure. Nevertheless, hydrocarbons (mostly methane) may still be found emanating from gaseous fuel vehicles. In all cases, the average THC measured during the evaporative tests were lower than from the RFG tests, but in a few cases the difference was not statistically significant.

Results from a subset of the vehicles (on which detailed speciation of the hydrocarbon emissions was performed) are summarized in Table 31. The general trend of these results was very consistent for the 2 labs where this analysis was performed. At both labs, the CNG emissions had lower average values of the four toxic emissions that were quantified, had lower PWT, lower average OFP, and lower

average SR. These differences were all deemed statistically significant at the 95% confidence level.

DODGE B250 VAN

The CNG and the gasoline Dodge B250 vans are full-size passenger vans equipped with a 5.2 L V8 engine. Both models have multi-point fuel injection and 4 speed automatic transmissions. The gasoline model was certified to EPA Tier 0 standards. The CNG model had received a waiver on emissions certification. The vehicles tested in this project were a mixture of 1992 and 1994 model year vans. Figure 30 shows the 1992 model year CNG Dodge van.

The gasoline model has a 35-gallon fuel tank, and the CNG model was equipped with 3 or 4 fuel cylinders mounted under the vehicle. The 3-cylinder configuration gives a capacity of 11.1 equivalent gallons and the 4-cylinder configuration gives a capacity of 15.7 equivalent gallons.



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Figure 30. The 1992 CNG Dodge B250 van

Two rounds of testing were completed on the Dodge B250 vans at Lab 1, and three rounds were completed at Labs 2 and 3. At Lab 1, 10 CNG vans and 8 gasoline controls were tested in both rounds. The vans tested at Lab 2 in all 3 rounds totaled 12 CNG vehicles and 13 gasoline vehicles. At Lab 3, 15 CNG vehicles and 14 gasoline models were tested in all 3 rounds. Mileage ranges and average odometer readings for the B250 vans tested at the three labs are listed in

Tables 32, 33, and 34. All data for the Dodge B250 vans can be found in Appendix A.

Regulated Emissions

Table 35 lists the average emissions values for the B250 vans tested at Lab 1 along with the percent difference and an indication of whether the differences are statistically significant at the 95% confidence level.

Table 36 lists the values for the vans

tested at Lab 2 and Table 37 for those tested at Lab 3. Figures 31–33 show the graphical representation of the average regulated and CO₂ exhaust emissions for the Dodge B250 vans tested at Labs 1, 2, and 3, respectively. Regulated emissions results for both the CNG and gasoline vans were well below the Tier 0 standard. The CNG vans, although not certified, tended to be below the more stringent Tier 1 standard.

Average NMHC emissions are shown in Figures 31a, 32a, and 33a for Labs 1, 2, and 3, respectively. All NMHC values were not only below the Tier 0 full useful life standard of 0.67 g/mi, but were also below the more stringent Tier 1 full useful life standard of 0.4 g/mi. NMHC emissions for the B250 vans were significantly lower in the CNG model for all 3 labs. Lab 1 showed the largest percent difference at approximately 94% lower for the CNG model during both rounds.

Lab 2 showed a 76% to 85% decrease in NMHC for the CNG model. Lab 3 showed a decrease in NMHC of 81% in Round 1, 41% in Round 2, and 45% in Round 3. The higher percentage for Lab 1 could be due partially to the discrepancy in odometer reading between the CNG and gasoline models. The average odometer for the CNG vans was 5,412 miles in Round 1 and 12,154 miles in Round 2. In contrast, the average odometer for the gasoline model was 39,749 miles and 45,755 miles for Rounds 1 and 2, respectively. All of the vans tested at Lab 1 were from the 1994 model year. Round-to-round comparisons at Lab 1 showed a significant increase in NMHC for the RFG tests in Round 2, but no significant difference between rounds for the CNG tests at Lab 1. At Lab 2, the CNG tests showed a significant increase from Round 1 to Round 2, and the RFG tests increased significantly from Round 2 to Round 3. Lab 3 CNG tests increased significantly

Table 32. Odometer Readings for the Dodge B250 Van Tested at Lab 1

	CNG		Gasoline	
Round	1	2	1	2
No. vehicles tested	10	10	10	8
Odometer (miles)				
Average	5,412	12,154	39,749	45,755
Maximum	6,611	15,527	107,350	60,261
Minimum	3,455	8,047	23,991	33,050

Table 33. Odometer Readings for the Dodge B250 Van Tested at Lab 2

	CNG			Gasoline		
Round	1	2	3	1	2	3
No. vehicles tested	12	12	12	13	13	13
Odometer (miles)						
Average	7,246	11,778	15,633	11,429	18,327	27,037
Maximum	15,026	24,824	30,050	22,195	32,165	57,099
Minimum	3,951	5,377	6,243	3,527	3834	9,363

Table 34. Odometer Readings for the Dodge B250 Van Tested at Lab 3

	CNG			Gasoline		
Round	1	2	3	1	2	3
No. vehicles tested	15	15	15	14	14	14
Odometer (miles)						
Average	6,978	12,051	18,515	13,321	17,338	19,670
Maximum	22,245	29,585	45,147	30,493	36,629	38,485
Minimum	2,121	3,455	6,782	3,875	5,210	6,720

Table 35. Average Emissions Results from the Dodge B250 Van Tested at Lab 1

	Round 1				Round 2			
	CNG	STD-RFG	Percent Difference	Sig. Fuel Effect?	CNG	STD-RFG	Percent Difference	Sig. Fuel Effect?
Regulated Emissions (g/mi)								
NMHC	0.018	0.323	-94.3%	y	0.022	0.362	-93.8%	y
THC	0.288	0.387	-25.7%	y	0.383	0.431	-11.1%	y
CO	0.651	5.615	-88.4%	y	0.734	6.846	-89.3%	y
NO _x	0.287	0.858	-66.6%	y	0.521	0.888	-41.3%	y
Evaporative Emissions (g/test)								
Total Evaporative	0.0684	0.6999	-90.2%	y	0.4501	0.8749	-48.5%	y
Greenhouse Gases (g/mi)								
CO ₂	539.16	637.87	-15.5%	y	526.54	617.84	-14.8%	y
CH ₄	0.27	0.078	244.8%	y	0.362	0.085	325.2%	y
Aldehydes (mg/mi)								
HCHO	2.08	6.45	-67.7%	y	2.31	6.13	-62.3%	y
CH ₃ CHO	0.17	1.25	-86.7%	y	0.26	1.38	-80.9%	y
Fuel Economy	12.97	13.49	-3.9%	y	12.5	13.73	-9.0%	y

Table 36. Average Emissions Results from the Dodge B250 Van Tested at Lab 2

	Round 1				Round 2				Round 3			
	CNG	STD RFG	Percent Difference	Sig. Fuel Effect?	CNG	STD RFG	Percent Difference	Sig. Fuel Effect?	CNG	STD RFG	Percent Difference	Sig. Fuel Effect?
Regulated Emissions (g/mi)												
NMHC	0.045	0.306	-85.4%	y	0.071	0.325	-78.1%	y	0.083	0.352	-76.3%	y
THC	0.759	0.367	106.6%	y	1.017	0.387	163.2%	y	1.273	0.416	205.7%	y
CO	1.747	5.994	-70.9%	y	1.604	5.954	-73.1%	y	1.393	7.079	-80.3%	y
NO _x	0.547	0.762	-28.3%	n	0.757	0.810	-6.5%	n	1.290	0.853	51.2%	y
Evaporative Emissions (g/test)												
Total Evaporative	0.406	0.621	-34.7%	y	0.317	0.803	-60.5%	y	0.267	1.060	-74.9%	y
Greenhouse Gases (g/mi)												
CO ₂	559.5	667.9	-16.2%	y	547.2	644.5	-15.1%	y	548.1	644.4	-14.9%	y
CH ₄	0.716	0.075	853.7%	y	0.94	0.077	1,127.7%	y	1.192	0.080	1,386.7%	y
Aldehydes (mg/mi)												
HCHO	8.14	7.41	9.9%	n	6.09	6.43	-5.4%	n	8.79	5.79	51.9%	y
CH ₃ CHO	0.37	1.71	-78.3%	y	0.37	1.56	-76.3%	y	0.50	1.96	-74.6%	y
Fuel Economy	11.64	13.08	-11.0%	y	11.89	13.45	-11.6%	y	11.86	13.51	-12.2%	y

from Round 1 to 2, but the RFG tests did not show a significant difference between the rounds.

The average CO emissions for the B250 vans tested at the 3 labs are shown in Figures 31b, 32b, and 33b. Average results were below the Tier 0 full useful life standard for CO.

Although the CNG vans were not certified, the average CO emissions for these vehicles were below the more stringent Tier 1 levels at all 3 labs.

The average CO emissions from the CNG vehicles at Lab 1 were 88% and 89% lower than the RFG emissions for Rounds 1 and 2, respectively. Lab 2 showed a decrease in CO for the CNG vans of 71% in Round 1, 73% in Round 2, and 80% in Round 3.

Lab 3 showed a decrease of 35.5% in Round 1, 48% in Round 2, and 53% in Round 3. Round-to-round comparisons of CO emissions at Lab 1 show a significant increase in Round 2 for the RFG tests, but no significant dif-

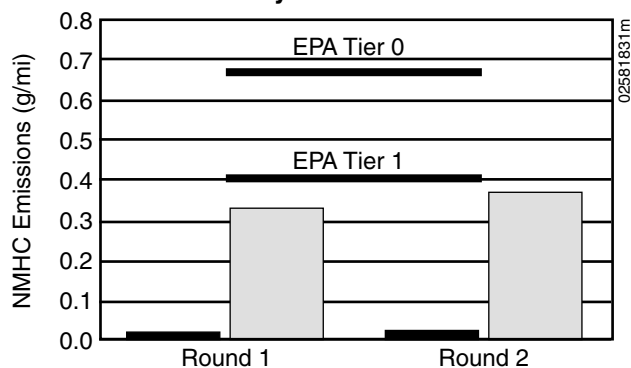
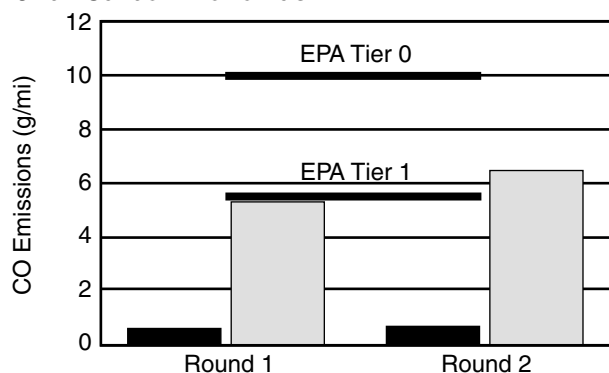
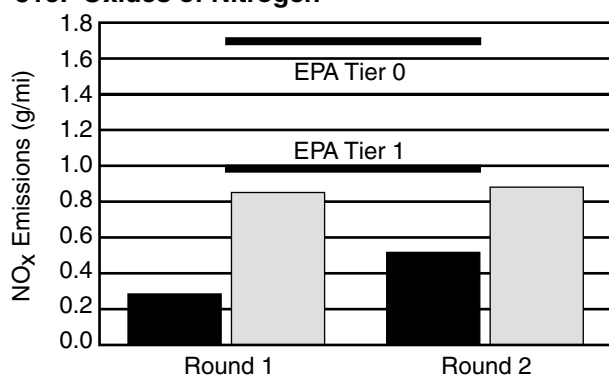
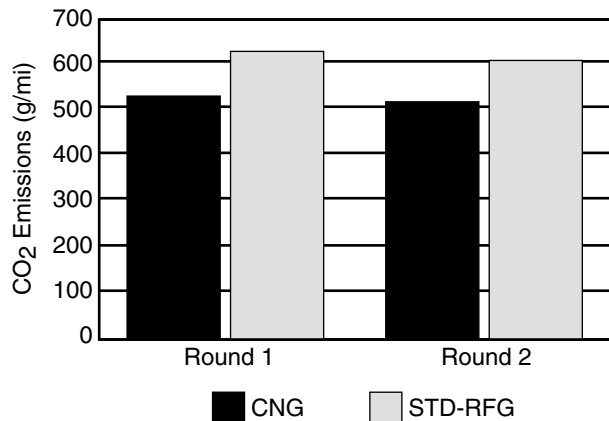
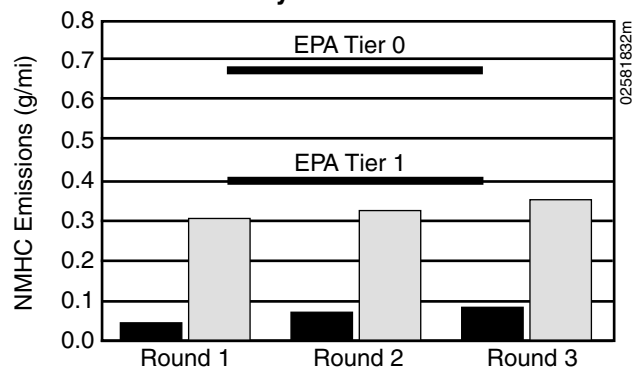
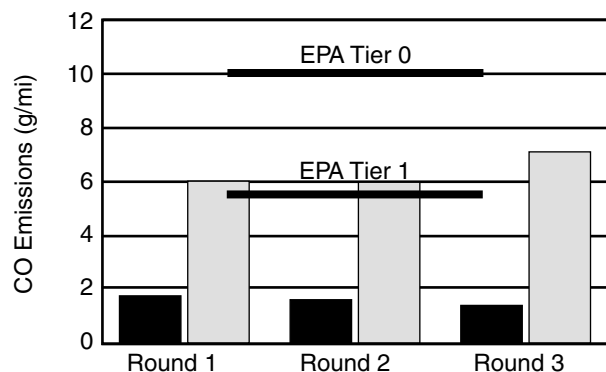
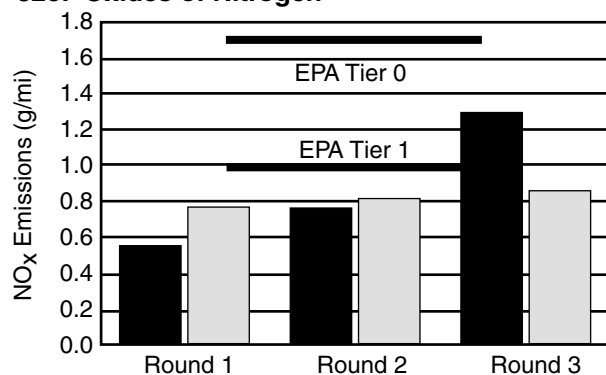
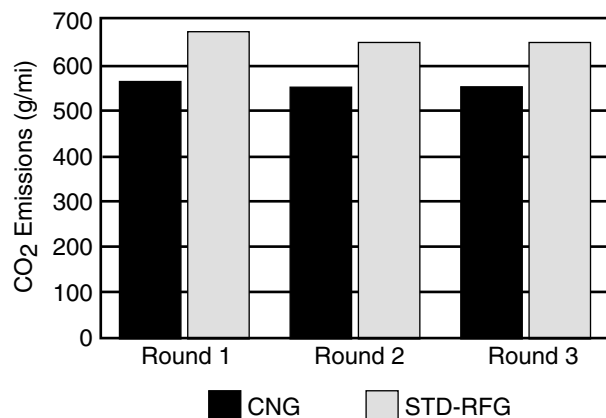
ference between rounds for the CNG tests. The only significant increase in CO emissions at Lab 2 was for the RFG tests from Rounds 2 to 3. The CO emissions for the CNG vans at Lab 2 showed a slight downward trend that was not significant at the 95% confidence level. This same trend was seen with the CNG vans tested at Lab 3. The RFG vans at Lab 3 showed a significant CO increase in Round 2 and a significant decrease in Round 3.

Average NO_x emissions for the B250s tested at the 3 labs are shown in Figures 31c, 32c, and 33c. The average NO_x emissions for the B250 vans were below the federal Tier 0 standard of 1.7 g/mi. The average NO_x emissions for the CNG vans were lower than that of the gasoline models except for the third round at Lab 2. At Lab 1, the CNG emissions were 66.5% lower in Round 1 and 41% lower in Round 2. Lab 3 also

followed this trend; Round 1 CNG emissions were 45.5% lower, Round 2 were 31% lower, and Round 3 were 10.7% lower. The average NO_x emissions for both van models were below the Tier 0 as well as the more stringent Tier 1 limits. The exception to this trend was seen at Lab 2. Rounds 1 and 2 showed a decrease in NO_x emissions for the CNG model, but this difference was not significant. In Round 3, the CNG average for NO_x was 51% higher than the average for the gasoline model. This was mainly caused by one high-emitting van, which was not tagged as an outlier. During Bag 3 of the FTP on this van, the check engine light came on, indicating a possible problem. If this value is removed, the CNG average is lowered to 0.997 g/mi, but this is still higher than the gasoline average by 16.9%. Round-to-round comparisons of NO_x emissions at all 3 labs showed an increasing trend for the CNG vans

Table 37. Average Emissions Results from the Dodge B250 Van Tested at Lab 3

	Round 1				Round 2				Round 3			
	CNG	STD RFG	Percent Difference	Sig. Fuel Effect?	CNG	STD RFG	Percent Difference	Sig. Fuel Effect?	CNG	STD RFG	Percent Difference	Sig. Fuel Effect?
Regulated Emissions (g/mi)												
NMHC	0.049	0.257	-80.9%	y	0.179	0.304	-41.1%	y	0.170	0.310	-45.2%	y
THC	0.710	0.311	128.1%	y	0.741	0.353	109.9%	y	0.797	0.365	118.4%	y
CO	2.563	3.974	-35.5%	y	2.458	4.713	-47.9%	y	1.828	3.877	-52.9%	y
NO _x	0.379	0.695	-45.5%	y	0.506	0.738	-31.4%	y	0.709	0.794	-10.7%	n
Evaporative Emissions (g/test)												
Total Evaporative	0.571	1.041	-45.2%	n	0.524	1.39	-62.3%	y	0.764	1.35	-43.4%	y
Greenhouse Gases (g/mi)												
CO ₂	502.3	616.0	-18.5%	y	494.1	604.8	-18.3%	y	488.1	606.25	-19.5%	y
CH ₄	0.66	0.054	1,134.5%	y	0.557	0.049	1,030.6%	y	0.617	0.055	1,026.3%	y
Aldehydes (mg/mi)												
HCHO	1.68	3.62	-53.6%	y	1.82	3.85	-52.7%	y	1.86	3.87	-51.9%	y
CH ₃ CHO	0.089	1.03	-91.3%	y	0.196	1.06	-81.4%	y	0.2	1.08	-81.4%	y
Fuel Economy	13.32	13.93	-4.4%	y	13.66	14.16	-3.5%	y	13.86	14.15	-2.0%	y

31a: Non-Methane Hydrocarbon**31b: Carbon Monoxide****31c: Oxides of Nitrogen****31d: Carbon Dioxide****Figure 31. Emissions results from the Dodge B250 van tested at Lab 1****32a: Non-Methane Hydrocarbon****32b: Carbon Monoxide****32c: Oxides of Nitrogen****32d: Carbon Dioxide****Figure 32. Emissions results from the Dodge B250 van tested at Lab 2**

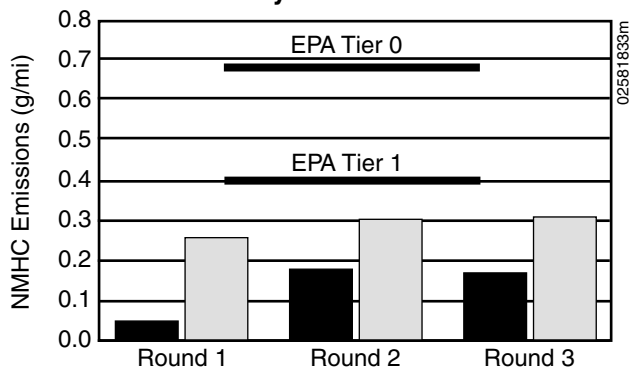
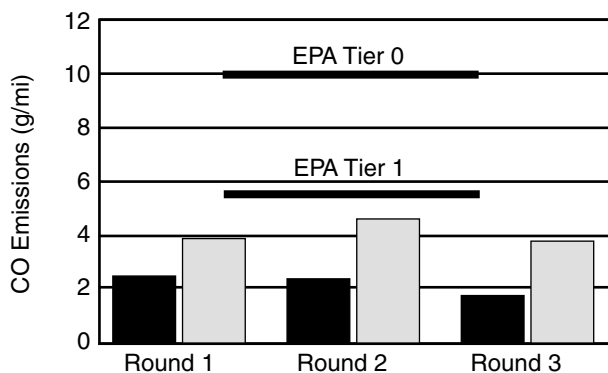
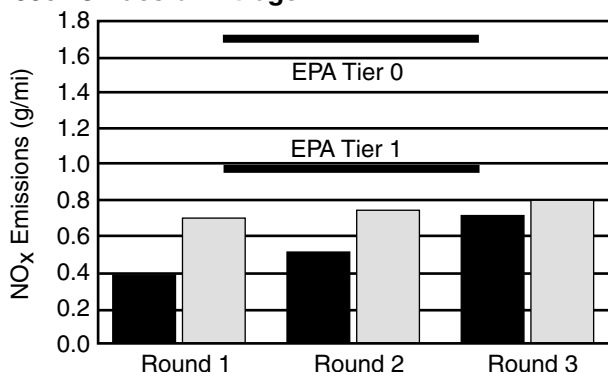
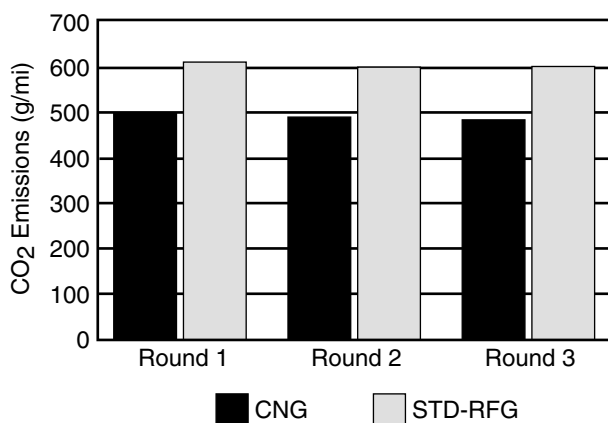
33a: Non-Methane Hydrocarbon**33b: Carbon Monoxide****33c: Oxides of Nitrogen****33d: Carbon Dioxide**

Figure 33. Emissions results from the Dodge B250 van tested at Lab 3

that tended to be significant. The differences between rounds for the RFG vans showed no significant difference at any of the labs.

Evaporative Emissions

CNG vehicles were designed with sealed fuel systems. To determine if the test vans were experiencing any leaks or "weepage" at any point in the natural gas fuel system, a modified evaporative test was performed. The gasoline vans received the standard evaporative test, which includes a heat build on the fuel tanks. The CNG vans were placed in the SHED for the two prescribed 1-hour tests, but without heating the tanks.

Average evaporative emissions for Labs 1, 2, and 3 are listed in Tables 35–37 and shown in Figures 34–36. The average evaporative emissions for the B250 van were well below the Tier 1 and Tier 0 limit of 2 g per test for all rounds at each lab. "Evaporative" HC emissions from the modified evaporative tests on the CNG vans were significantly lower than the evaporative emissions for the standard models for all labs during all test rounds. Evaporative emissions for the CNG vans tested at Lab 1 were 90% lower than those from the gasoline vans in Round 1 and 48.5% lower in Round 2. The CNG vans tested at Lab 2 showed larger differences of 35%, 61%, and 75% lower than the gasoline controls for Rounds 1, 2, and 3, respectively. Lab 3 also showed decreases for the CNG vans, from 43% to 62%. These differences tended to be statistically significant at the 95% confidence level.

Round-to-round comparisons showed significant increases for both fuels at Lab 1. The CNG vans at Lab 2 showed no significant difference between rounds and the control vans showed a steady increase in evaporative emissions that was only significant between Round 2 and Round 3. The CNG vans tested at Lab 3 also showed no significant difference between rounds. The evaporative emissions for the control vans at Lab 3 showed an increase in Round 2 and a decrease in Round 3. Neither of these differences, however, was statistically significant.

Greenhouse Gases

The average CO₂ emissions for the CNG vans were consistently lower than the average for the gasoline controls. Labs 1 and 2 showed a decrease of around 15% for all rounds. Lab 3 had a slightly higher percent decrease at approximately 19% for the 3 rounds. The differences in CO₂ emissions between CNG and RFG were statistically significant. The differences between rounds for both van types at all 3 labs tended not to be significant at the 95% confidence level.

Because CNG is 95% CH₄, emissions of this greenhouse gas are expected to be significantly higher for the CNG vans.

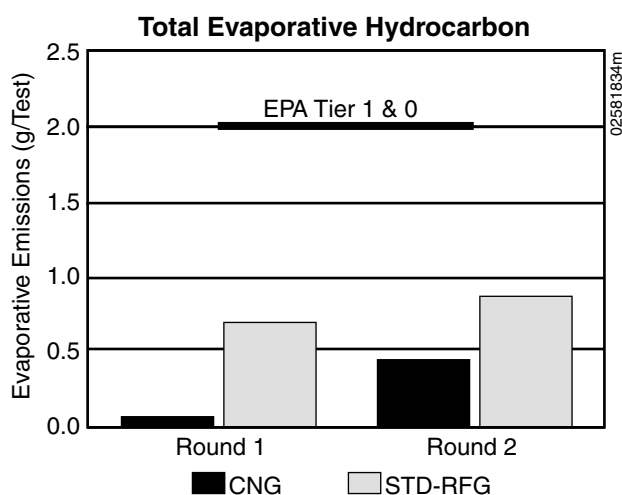


Figure 34. Evaporative emissions results from the Dodge B250 van tested at Lab 1

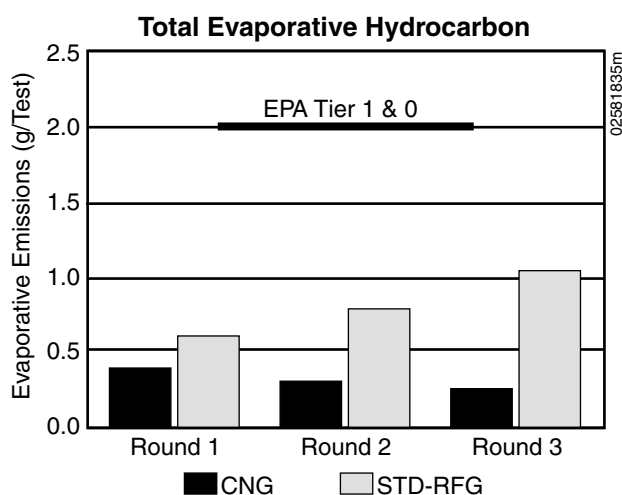


Figure 35. Evaporative emissions results from the Dodge B250 van tested at Lab 2

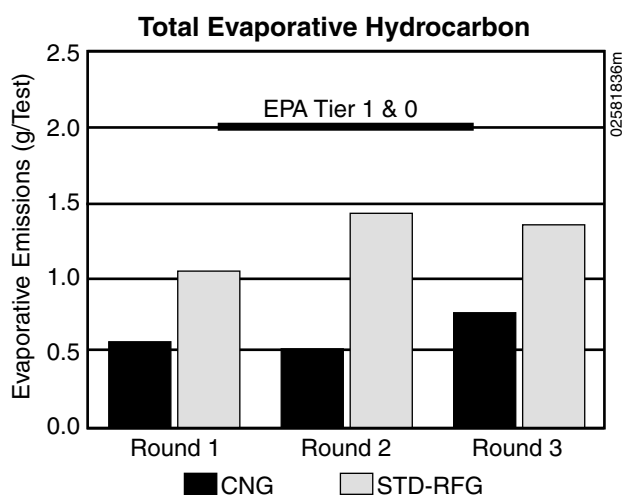


Figure 36. Evaporative emissions results from the Dodge B250 van tested at Lab 3

Differences in CH₄ emissions between the CNG tests and the RFG tests range from 245% higher to 1,387% higher. Round-to-round comparisons of CH₄ emissions at Labs 1 and 2 showed significant increases for the CNG tests over time. Lab 3 showed a significant increase in CH₄ for the CNG tests in Round 2, but no significant difference in Round 3. The RFG tests showed no significant difference in CH₄ emissions between rounds at any of the labs.

Aldehydes

Figures 37–39 present the average aldehyde emissions for the Dodge B250 vans at each lab. In general, aldehyde emissions from the CNG vans were much lower than those from the gasoline vans. The exception to this was the formaldehyde emissions at Lab 2. Labs 1 and 3 showed similar values between fuels for both formaldehyde and acetaldehyde with the CNG vans testing significantly lower than the gasoline control vans. Reductions in formaldehyde at Lab 1 were approximately 68% in Round 1 and 62% in Round 2. Lab 3 showed reductions in formaldehyde of approximately 54%, 53%, and 52% in Rounds 1, 2, and 3 respectively. Acetaldehyde emissions for the CNG vans at Lab 1 were 87% lower than those from the conventional vans in Round 1 and 81% lower in Round 2. Lab 3 showed similar reductions in acetaldehyde of 91% in Round 1 and 81% in Rounds 2 and 3.

Average formaldehyde emissions for the B250 vans tested at Lab 2 were not significantly different between fuels for the first 2 rounds. The CNG vans tested 9.9% higher than the gasoline controls in Round 1 and 5.4% lower in Round 2. Round 3, however, showed a significant increase in formaldehyde emissions for the CNG vans (51.8%). This could be due in part to the van mentioned earlier (on which the check engine light came on during the last phase of the FTP). The formaldehyde value for this van was considerably higher than that of the other vans tested. Removal of this value, which was not identified as an outlier, would reduce the percent difference to 26%, but the CNG average is still greater than that of the conventional model. Acetaldehyde emissions at Lab 2 agree with the other 2 labs, with the CNG vans testing significantly lower than the gasoline vans. The average acetaldehyde emissions for the CNG vans tested at Lab 2 were 78% lower than those from the conventional model van in Round 1, 76% lower in Round 2, and 75% lower in Round 3. The differences between rounds for aldehydes at all 3 labs tended to be not significant at the 95% confidence level.

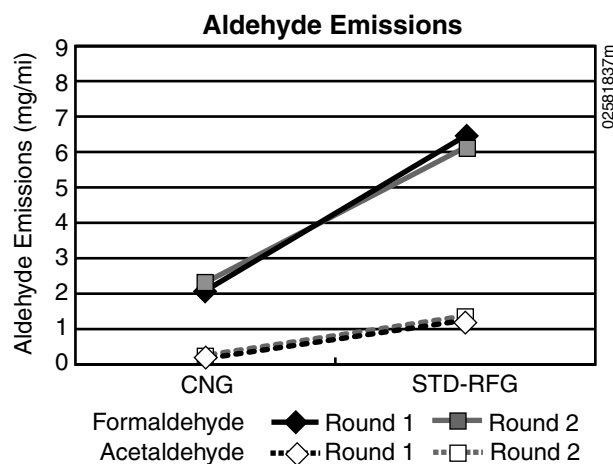


Figure 37. Aldehyde emissions from the Dodge B250 van tested at Lab 1

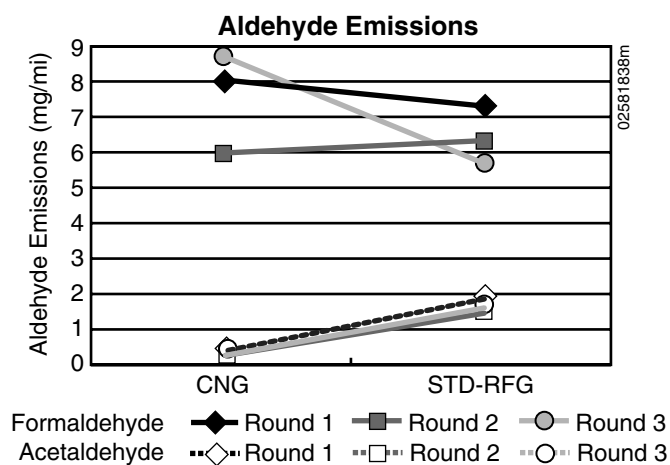


Figure 38. Aldehyde emissions from the Dodge B250 van tested at Lab 2

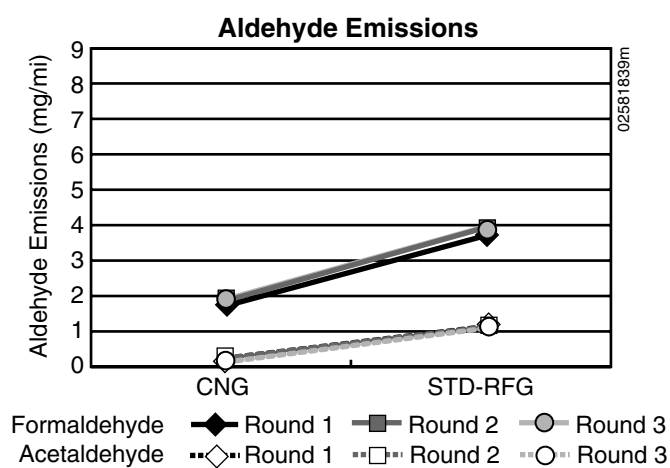


Figure 39. Aldehyde emissions from the Dodge B250 van tested at Lab 3

Table 38. Toxic Emissions from the Dodge B250 Van Tested at Lab 1

	CNG		STD-RFG		Percent Difference	Sig. Fuel Effect?
	Measured Value (mg/mi)	PWT	Measured Value (mg/mi)	PWT		
HCHO	1.878	0.086	5.741	0.264	-67.4%	y
CH ₃ CHO	0.152	0.001	1.167	0.009	-88.9%	y
1,3-butadiene	0	0	2.1	2.1	-100.0%	y
Benzene	0.060	0.0018	14.15	0.425	-99.6%	y
Total	2.09	0.089	23.16	2.798	-96.8%	y

Table 39. Toxic Emissions from the Dodge B250 Van Tested at Lab 3

	CNG		STD-RFG		Percent Difference	Sig. Fuel Effect?
	Measured Value (mg/mi)	PWT	Measured Value (mg/mi)	PWT		
HCHO	2.007	0.092	3.467	0.159	-42.1%	y
CH ₃ CHO	0.171	0.0014	0.989	0.0079	-82.3%	y
1,3-butadiene	0.014	0.014	1.985	1.985	-99.3%	y
Benzene	0.25	0.0075	11.179	0.335	-97.8%	y
Total	2.442	0.115	17.62	2.488	-95.4%	y

Potency-Weighted Toxics and Ozone-Forming Potential

Hydrocarbon speciation was performed on a percentage of the Dodge B250 vans at Labs 1 and 3. Four CNG and three gasoline control vans speciated at Lab 1. The vans receiving full speciation at Lab 3 totaled four CNG and five gasoline control vans.

Tables 38 and 39 present the comparisons between van models for PWT emissions at Labs 1 and 3, respectively. Figures 40 and 41 show the results graphically. The aldehyde averages listed include the results for only those vehicles that were speciated. These results show a significant advantage in using CNG fuel over gasoline. All the toxics for the CNG vans tested at Lab 1 were significantly lower than the averages for the RFG tests. Lab 1 reported no

1,3-butadiene present in the CNG tests, which represented a 100% decrease over the RFG levels. Total PWT for the CNG vans was 96.8% lower than that of the gasoline control vans. Lab 3 showed agreement with Lab 1. All toxics for the CNG vans were significantly lower than the gasoline controls. Total PWT for the CNG vans was 95.4% lower than that of the gasoline controls.

Tables 40 and 41 present the NMOG, OFP, and SR results for the Dodge B250 vans. Average NMOG for the CNG vans was significantly lower than the average for the gasoline models. The OFP and SR results are graphically presented in Figures 42 and 43. OFP from the CNG vans was significantly lower than that from the gasoline vans by 96.5% at Lab 1 and 81% at Lab 3. SR also showed significant reductions for the CNG vans,

approximately 46% at Lab 1 and 56% at Lab 3.

Fuel Economy

Because CNG is a gaseous fuel, it must be converted to gallons of gasoline equivalent (gge) in order to make a comparison with a liquid fuel. An equivalent gallon of CNG is the quantity of CNG that has the same energy content as a gallon of gasoline. A gallon of RFG has 111,960 Btu. Approximately 121 standard cubic foot (scf) of test CNG contains the same Btu as RFG. Therefore, 121 scf equals one gge.

Fuel economy averages for the CNG van are listed in Tables 35–37 as miles per equivalent gallon of gasoline. Average fuel economy for the CNG Dodge B250 vans was only slightly less than that of the conventional models. All three labs were in

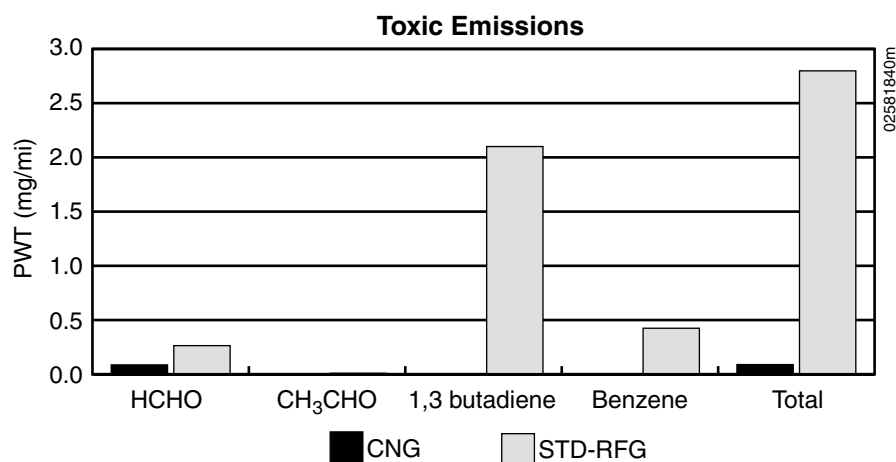


Figure 40. PWT emissions from the Dodge B250 van tested at Lab 1

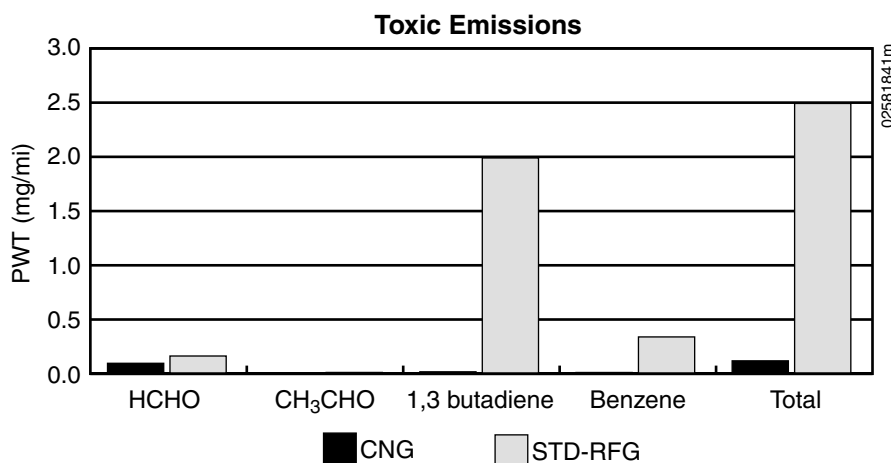


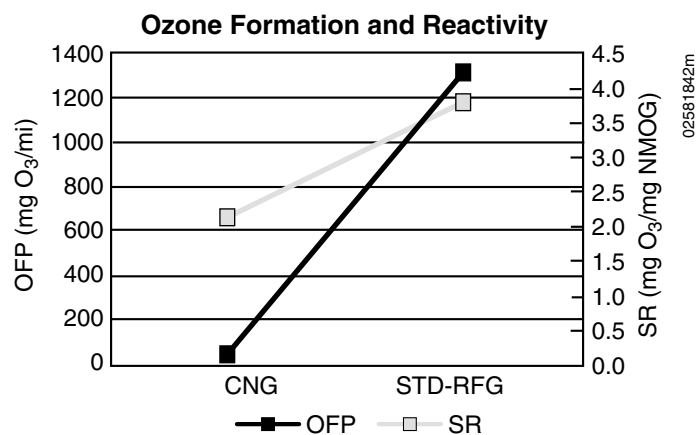
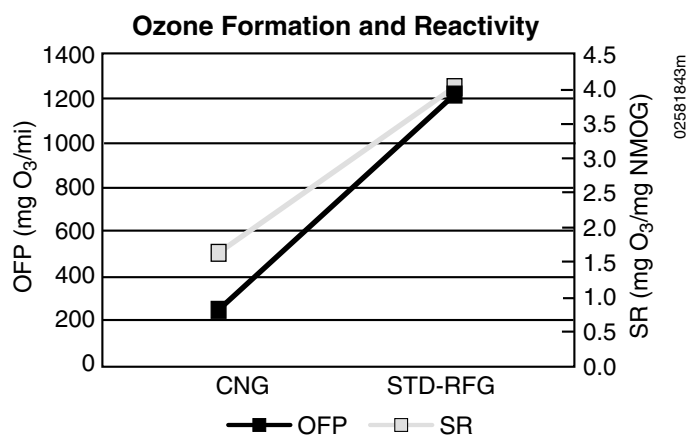
Figure 41. PWT emissions for the Dodge B250 van tested at Lab 3

Table 40. OFP for the Dodge B250 van Tested at Lab 1

	CNG	STD-RFG	Percent Difference	Sig. Fuel Effect?
NMOG (mg/mi)	21.95	354.49	-93.8%	y
OFP (mg O ₃ /mi)	45.2	1,305.31	-96.5%	y
SR (mg O ₃ /mg NMOG)	2.06	3.836	-46.3%	y

Table 41. OFP for the Dodge B250 Van Tested at Lab 3

	CNG	STD-RFG	Percent Difference	Sig. Fuel Effect?
NMOG (mg/mi)	76.48	308.72	-75.2%	y
OFP (mg O ₃ /mi)	233.27	1208.9	-80.7%	y
SR (mg O ₃ /mg NMOG)	1.768	4.031	-56.1%	y

**Figure 42. OFP and SR for the Dodge B250 van tested at Lab 1****Figure 43. OFP and SR for the Dodge B250 van tested at Lab 3**

agreement, with percent differences ranging from 2% lower in the CNG vans to approximately 12% lower. These differences in fuel economy between CNG and RFG were significant for all rounds at all 3 labs.

DODGE CARAVAN MINIVAN

The 1994 Dodge Caravan is a mini-van equipped with a 3.3 L V6 engine (Figure 44). Both models were certified to EPA Tier 1 emissions levels. Because there was a limited number of vehicles available, these vans were only tested in one round. There were 13 dedicated CNG vans and 6 standard gasoline vans tested. Mileage ranges and average odometer readings for the Caravans tested in this program are listed in Table 42. Detailed hydrocarbon speciation was not performed on these vehicles.

Regulated Emissions

Table 43 lists the average emissions for the CNG and conventional model Caravans along with the percent differences and an indication of whether the differences are statistically significant at the 95% confidence level. Figure 45 shows the comparison of average regulated emissions and CO₂ for these vans. All regulated emissions results for the Caravans were well below the EPA Tier 1 standard. When comparing regulated emissions for the CNG Caravan to those of the gasoline control vans, there was a sig-

Table 42. Odometer Readings for the Dodge Caravan Minivan

	CNG	Gasoline
No. vehicles tested	6	13
Odometer (miles)		
Average	17,888	6,683
Maximum	20,696	14,282
Minimum	15,527	3,817



Warren Grez, NREL/PIX02487

Figure 44. The 1994 CNG Dodge Caravan minivan

Table 43. Average Emissions Results from the Dodge Caravan Minivan

	Round 1			
	CNG	STD-RFG	Percent Difference	Sig. Fuel Effect?
Regulated Emissions (g/mi)				
NMHC	0.022	0.147	-84.8%	y
THC	0.166	0.169	-2.1%	n
CO	0.364	1.552	-76.5%	y
NO _x	0.187	0.296	-36.9%	n
Evaporative Emissions (g/test)				
Total Evaporative	0.311	0.323	-3.7%	n
Greenhouse Gases (g/mi)				
CO ₂	389.54	467.22	-16.6%	y
CH ₄	0.142	0.028	415.0%	y
Aldehydes (mg/mi)				
HCHO	4.036	3.468	16.4%	n
CH ₃ CHO	0.322	0.902	-64.3%	y
Fuel Economy				
Fuel Economy	17.45	18.84	-7.3%	y

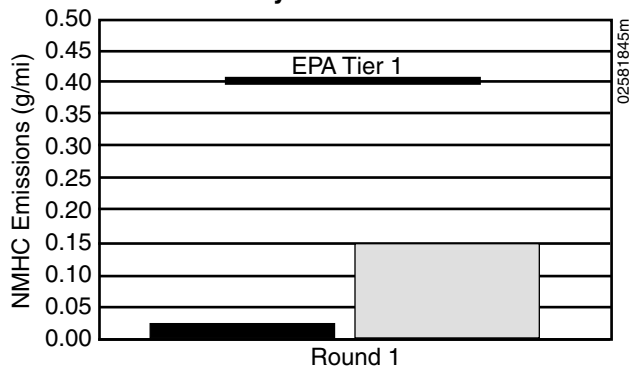
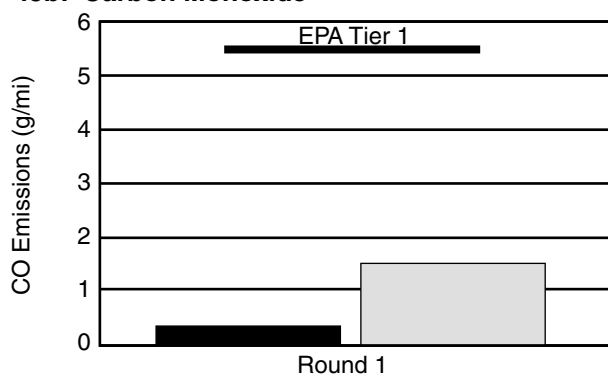
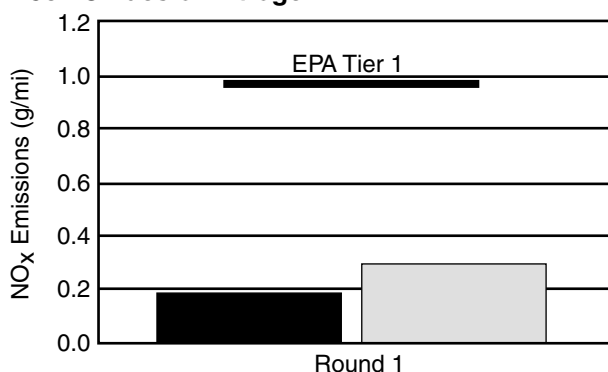
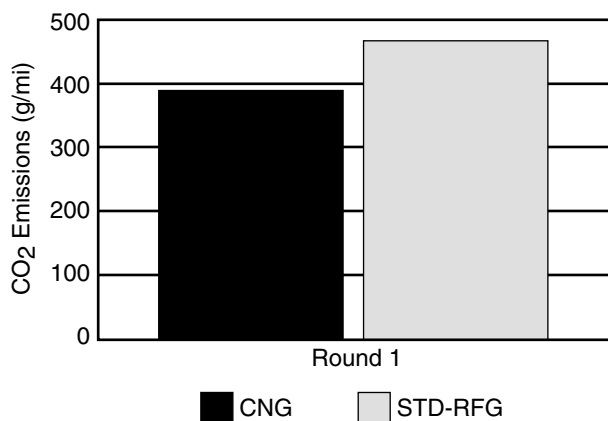
45a: Non-Methane Hydrocarbon**45b: Carbon Monoxide****45c: Oxides of Nitrogen****45d: Carbon Dioxide**

Figure 45. Emissions results from the Dodge Caravan minivan

nificant decrease in NMHC, a significant decrease in CO, and a decrease in NO_x that was not significant at the 95% confidence level. NMHC was 85% lower for the CNG model. CO emissions were 76.5% lower and NO_x emissions were 37% lower for the CNG vans.

Evaporative Emissions

The same modified evaporative emissions test described in the section on the B250 vans was performed on the CNG Dodge Caravans. Results for the Dodge Caravans are listed in Table 36 and graphically illustrated in Figure 46. Average "evaporative" emissions for both CNG and gasoline models were well below the Tier 0 and Tier 1 limit of 2 g. As with the B250 van, the CNG Caravan emitted measurable HC during the test, but they were lower than the average evaporative emissions from the gasoline control. The reduction was 3.7%, which was not statistically significant at the 95% confidence level.

Greenhouse Gases

As with the regulated emissions, average CO₂ emissions were significantly lower for the CNG Caravans. Values for the CNG vans were approximately 16% lower than those of their gasoline counterparts. Average CH₄ emissions, as expected, were higher for the CNG Caravans. Although the values for each van type were quite low, the CNG model showed a 415% increase in CH₄ over the gasoline model.

Aldehydes

Aldehyde emissions levels for the Dodge Caravans are shown in Figure 47. Although the formaldehyde emissions from the CNG minivans were 16% higher than the gasoline model, this difference was not statistically significant at the 95% confidence level. Acetaldehyde emissions were 64% lower for the

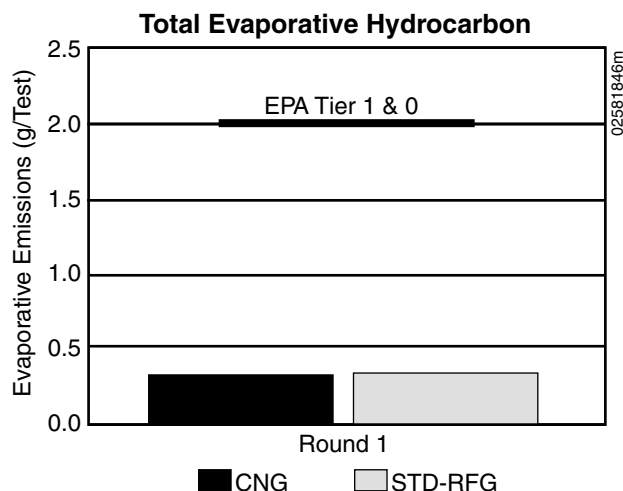


Figure 46. Evaporative emissions results from the Dodge Caravan minivan

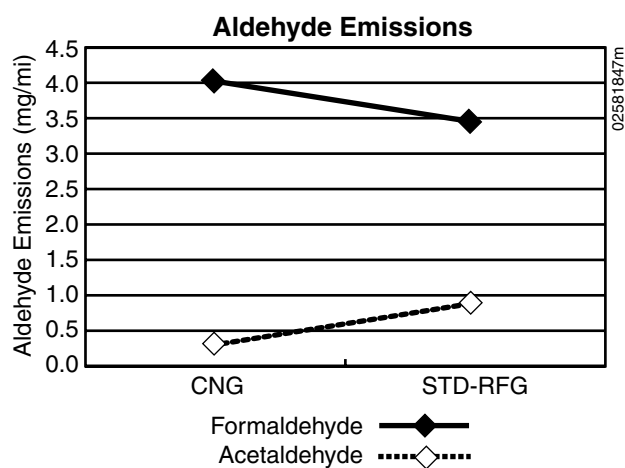


Figure 47. Aldehyde emissions from the Dodge Caravan minivan

CNG model compared to the RFG results.

Fuel Economy

Fuel economy comparisons for the Dodge Caravan showed very little difference when compared on a gasoline gallon equivalent between the CNG and standard models. The fuel economy for the CNG minivans was approximately 7% lower than that of the standard gasoline model.